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CHINESE AVIATION APPLICATIONS

by

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CHINESE AVIATION APPLICATIONS

Liu Jiyu

ABSTRACT From the first GPS test satellite entering into orbital operation on 22 February 1978 to the launching aloft of the 23d operational satellite on 28 October 1993, the GPS navigation and global positioning system has been in the midst of a net organization process which has gone on for 16 years. Moreover, it has created a GPS enterprise which is international in character. Several hundred thousand personnel were engaged with an output value of close to 10 billion U.S. dollars. This article introduces application benefits associated with GPS during the Gulf War as well as the results of applications in Chinese map making departments. Finally, two revelations are summarized from among GPS applications.

KEY WORDS GPS application Map making Economic benefit

As far as astronavigational technology is concerned, there are a good number of nations competing with each other in the development of new high technologies. Following along with rapid development in astronavigational technologies, the industrialization of space, the commercialization of space, and the militarization of space will become the focal points associated with the 21st century great power struggle for hegemony in space. "Whoever occupies space will then possess the earth." will become the prime motivation associated with the development of astronavigational technologies and will become the catalyst for the development of an outerspace economy based on astronavigational/electronic information technologies.

As far as the GPS navigation satellite global positioning system is concerned, it is one type of result from astronavigational technology which is associated with the highest application efficiencies and economic benefits. It is a second generation military use satellite navigation system developed by a combination of the three U.S. Army, Navy, and Air Force services. In conjunction with this, a combined office was set up with a specialized responsibility for the implementation of GPS plans and management. The combined office is set up within the Air Force astronavigation command in Los Angeles. Constituent personnel include representatives of the U.S. Army, Navy, Marine Corps, Defense Mapping Agency, Department of Transportation, NATO, and Australia. With regard to the objectives of the GPS system, the primary one is to provide real time, all weather, global navigation services for the three land, sea, and air services of the U.S. as well as its allies. However, development of GPS satellite applications clearly shows that the GPS system has already far, far exceeded its anticipated objectives. In civilian uses associated with a good number of countries, it has already produced surprising economic benefits. On a foundation of generally describing broad GPS satellite applications, this article puts forward suggestions for developing China's astronavigational application technology market.

I. HIGH BENEFITS OF GPS

Since the first commercial GPS receiver was introduced to the world in 1980--following along with the unceasing introduction into orbital operation of GPS experimental satellites and operational satellites--GPS is broadly applied day by day in navigation and positioning measurements associated with the domains of land, sea, and air. In conjunction with this, it led to a profound technological revolution in navigation and map

making enterprises. Looking at the current situation in depth, GPS satellites are producing the effects and influences described below.

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1. In Depth Development of Applications Created an International GPS Industry with Several Hundred Thousand Personnel Engaged in It and an Output Value of Close to Ten Billion U.S. Dollars.

At the beginning of the set up of the GPS system, the U.S. Defense Department's primary objective was to supply real time, all weather, and global navigation services for the three land, sea, and air services. In conjunction with this, it was used for a number of military objectives such as intelligence collection, nuclear detonation monitoring, as well as emergency communications, and so on. However, development of GPS satellite applications over more than 10 years clearly shows that navigation and positioning signals sent by GPS satellites are a type of information resource which can be shared with numberless users. As far as the broad usership associated with land, sea, air, and space is concerned, so long as they possess a receiver which is able to receive, track, transform, and measure GPS signals, it is then possible to measure with high precision and in all weather, seven dimensional status parameters and three dimensional attitude parameters. The uses are broad. Influences are great. Any other receiver equipment is far, far behind. It reaches up to spacecraft and down to fishing boats. In all cases, it is possible to make use of GPS signal receivers. Not only is this the case. GPS satellites entering into orbital operation also provide a type of new, all weather, high precision measurement technology for geodesy, geodynamics, geophysics, the kinetics of heavenly bodies, the science of manned spaceflight, global oceanography, and global metrology. Just taking GPS applications in map making as an example, GPS signals are capable of being used in the areas described below.

- (1) Measurement of global geodynamics parameters, designated as GPS global geodesy;
- (2) Surveying the set up of geodetic measurement control networks of a pan-national and regional character;
- (3) Setting up land and oceanic geodetic data and geodetic control networks for the sea bottom;
- (4) Monitoring the status of modern movements of the earth's plates and deformations in the earth's crust;

(5) Precise determinations of camera positions associated with instants in aviation and space flight photography. For example, on 29 September 1993, we made use of airborne Trimble 4000ST GPS dual frequency receivers in Beijing to obtain measurements for the positions of photographic stations associated with aviation cameras, as shown in Table 1.

(6) Used in design, construction, checks upon acceptance, and monitoring associated with engineering and construction.

(2) 名称	(3) 时元/s	(4) 摄站三维位置			(5) 有效值 /m	PDOP
		X/m	Y/m	Z/m		
GPS	263526.016	-2207623.021	4449448.840	4000095.540	0.116	3.38
GPS	263527.040	-2207742.894	4449342.038	4000158.208	0.106	3.38
(6) 摄站	263527.298	-2207773.569	4449316.624	4000175.637	0.108	3.38
GPS	263528.064	-2207864.644	4449241.169	4000227.385	0.115	3.38
GPS	263529.088	-2207980.555	4449130.077	4000293.189	0.086	3.38
(6) 摄站	263529.326	-2208009.199	4449106.838	4000310.310	0.088	3.38
GPS	263530.112	-2208103.797	4449030.090	4000366.851	0.094	3.38
GPS	263531.136	-2208220.803	4448923.791	4000433.368	0.135	3.38
(7) 说明		(8) 摄站时元 $t_1 = 263527.298165668s$			(8) 摄站时元 $t_2 = 263529.325913851s$	

Table 1 Results Associated with the Use of GPS to Make Precise Determinations of the Locations of Airborne Aviation Camera Photography Stations

Key: (2) Designation (3) Time Elements/s (4) Photography Station Three Dimensional Positions (5) Effective Values (6) Photography Stations (7) Explanation (8) Photography Station Time Elements

Following along with broad daily applications of GPS technology to a great many enterprises, the amount of demand for GPS signal receivers also follows along and rapidly increases. Statistics for January 1994 clearly show that, at the present time, internationally, there are 59 plants producing 315 types of GPS signal receivers used in land, sea, and air measurements. On the basis of predictions made by the U.S. Department of Defense and the Transportation Department, it is clearly shown that, in the years 1990-2003, as far as U.S. military and civilian land, sea, and air GPS users are concerned, there are almost linear increases year after year. It is forecast that by the end of this century users of the U.S. GPS alone will reach approximately 500 thousand. On the basis of predictions by U.S. Commerce Department Secretary Ronald Brown in midsummer of 1993, by the end of this century, Americans engaged in production associated with GPS industries will exceed 100 thousand. Output values are capable of reaching over 5 billion U.S. dollars. If consideration is given to the current status of GPS applications in a good number of countries such as Canada, Japan, Germany, France, U.K., Switzerland, Sweden, Norway, Russia, and so on, GPS has already become an international industry developing vigorously. It provides employment opportunities for hundreds of thousands of people. Output values are close to 10 billion U.S. dollars--becoming another model following in the footsteps of the market economy in astronavigational technology.

2. GPS Is an Efficiency Multiplier for Combat Weapons. GPS Is One of the Important Technological Conditions Associated With Winning Victories in War. The Military Economic Benefits Which It Produces During Wars Are Difficult to Express by the Use of Numbers.

During the Gulf War in the early spring of 1991, multinational units with the U.S. at their head were equipped with 17000 GPS receiver units for the three land, sea, and air services, producing economic benefits which are difficult to calculate with the use of numbers. For example, on the first night of "Desert Storm", the U.S. Air Force sent out 7 B-52G strategic bombers. 35 AGM-80C air launched cruise missiles were fired toward Iraq. These cruise missiles, which were fitted with GPS composite guidance, were able to change over from striking area targets to hitting point position targets--accurately striking at predetermined bombing locations and severely damaging important strategic targets, stringently defended by Iraqi forces, such as electric generating plants, electrical transmission stations, as well as military communications

facilities, and so on. This established the first great exploit for GPS used in war. Again, using aerial attacks as an example, the U.S. Air Force installed GPS receivers on all 251 F-16A/C fighters used in combat. They were used in order to implement such missions as strategic target attacks, controlling air space, suppressing air defense, intercepting enemy aircraft, as well as short range support, and so on. With the support of GPS technology, victories were won time after time in surprise moves.

In a total of over 13400 sorties flown, only 5 F-16A/C fighters were lost. These are the smallest losses in the history of world air combat and the single campaign with the best attack results. During the Gulf War, the three land, sea, and air services applied GPS in a number of amazing actual examples, fully demonstrating the huge potential of using GPS satellites to do navigation positioning. After the conclusion of the 1991 Gulf War, in the last ten days of September, a "GPS Military Uses Conference" was convened in Germany. It summarized in a comprehensive manner the plentiful combat results of the three land, sea, and air services from applications of GPS technology, arriving at the conclusions set out hereafter: GPS is an efficiency multiplier for combat weapons, and GPS is one of the important technological conditions for winning victory in the Gulf War.

After the conclusion of the Gulf War, in order to rebuild Kuwait, it was, first of all, necessary to clean up the battlefields. Within the clean up area the U.S. was responsible for, there were scattered one million two hundred fifty thousand dud rounds and 500 thousand land mines. U.S. personnel used GPS with regard to these duds and land mines, detecting their locations one by one. Going a step further, their destruction was carried out by explosives experts. In the clean up of one million seven hundred fifty thousand pieces of ordnance, only one person lost his life, creating a marvel of battlefield clean ups.

No matter whether it was during the war or after the war, GPS technology was capable, in all cases, of bringing to bear important effects and influences. As a result, the U.S. Senate Military Affairs Committee expressly stipulated that: "Beginning in the year 2000, if aircraft, ships, armored vehicles, and indirect fire weapons are not fitted with GPS receivers, they will then also not be able to obtain improvement or procurement funding." This type of use of legislative articles to stipulate weapons deployments is seldom seen. This also indicates that GPS will become one of the technological mainstays for winning victories in future wars.

3. As Far as Applications of GPS Technology in Groups of Low Orbit Communications Satellites Are Concerned, Communications Switching Associated with "The Four Seas Are One Village"

Provides Data Standards in Order to Pump Energy into Modality Changes Associated With Commercial Management and Marketing.

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Use is made of GPS signals to precisely determine orbital positions for low orbit spacecraft. This is important progress in recent years associated with GPS dynamic survey technologies. For example, if one wishes, through satellites, to measure distances for altitudes above the ocean surface--realizing research associated with global oceanography and global metrology--calculations clearly show that, in order to study ocean currents, tides, and detect information associated with disasterous sea conditions, it is then required that measurement precisions associated with the oceans and land forms reach $\pm 13\text{cm}$.

This means that orbital radial errors associated with oceanic height measurements of satellites should be not larger than $\pm 13\text{cm}$. If use is made of traditional surface orbit fixing observation networks to precisely determine oceanic height measurements for satellites, there is basically no way to reach orbital measurement precisions of $\pm 13\text{cm}$. As a result, there is nothing else to do but look for help from GPS dynamic measurement technologies. For this reason, on 10 August 1992, the U.S. aviation and astronavigation agency (NASA) and France's national space research center (CNES) combined to launch the Topex/Poseidon oceanic satellite. A Monarch model GPS receiver unit produced by the Motorola company was then installed. Processing of actual data measurements clearly showed that not only were orbital radial errors associated with the Topex/Poseidon satellite not greater than \pm (illegible)3cm. Moreover, it was also discovered that El Nino phenomena began, in August 1993, to form ceaselessly on the surface of the Pacific Ocean, leading to a thickening of the ocean surface warm water layers--threatening fishing industry production and influencing oceanic climates.

Projecting to the year 1998, as far as the U.S. Motorola company's low orbit satellite communications constellation made up by the use of 66 "Iridium satellites" is concerned, it is transcentury, transnational global communications high science and technology system engineering. After it is constructed, satellite communications users will only need hand held radio telephones. It is then possible--anywhere at any time--to "call through" to any receiving person within a global range--realizing the super long distance purchasing, data transmission, speech communications, and imagery facsimile associated with "The Four Seas Are One Village". With regard to communications switching associated with global communications, there is a need to know low orbit satellite ephemeris and user locations. With respect to providing data standards for signal switching, it is made just as convenient for customers to buy goods in the stores of other

countries as it is to purchase products in shops outside their front gates.

4. As Far as Chinese User Test Utilization of GPS Technology Is Concerned, Economic Benefits Are Obvious, Great Scientific and Technological Achievements Are Myriad, and Domains of Application Expand Without Ceasing.

In the middle period of the 1980's, Chinese map making enterprises began to use GPS satellite positioning technology to replace Transit satellite Doppler positioning measurements. On the vast land and national oceans of China, GPS positioning networks with various different uses were arrayed to do surveying. At the present time, such Chinese departments as map making, petroleum, earthquakes, geology, oceans, and so on, possess approximately 300 units of high precision geodetic model GPS receivers. For example, Wuhan Map Making Science and Technology College then possesses a total of 9 GPS receivers of three models and one GPS international tracking station. Besides the fact that, since April 1990, measurements associated with GPS satellite positioning networks were carried out in several tens of provincial cities and regions, there has also been development of theory and experimental research associated with airborne and satellite borne GPS measurements. Although it is difficult to estimate statistically the economic benefits produced by our applications of GPS, comparative measurement results associated with the U.S. and Germany, however, are able to act as our collateral evidence. From September 1983 to May 1984, in Germany's Eifel district, a top grade intensified network constructed from 35 point positions was set up. The practical realization of this network clearly shows that GPS positioning technology saves 85% of outside expenses compared to conventional measurement technologies. U.S. statistics clearly show that using conventional geodetic survey technology to set up one first grade horizontal control point requires the spending of approximately 7000 U.S. dollars. Using GPS satellite positioning technology to set up a control point with the same level of precision only requires spending 2000 U.S. dollars--saving 71.43% of the costs. China has approximately 50 thousand first and second level triangle points and lead line points. If estimates are calculated on the basis of U.S. expense standards, GPS satellite positioning technology will cause China to save approximately 25 million U.S. dollars in outlays. This can be used in order to buy close to 900 geodetic model GPS signal receivers. To say it another way, economic benefits are six or seven times the investments. As far as the introduction of GPS positioning technology to the world is concerned--for oceanic chart making--in particular, for oceanic geodesy--a new

technological path has been opened up. On the 3 million square kilometers of national ocean that start at the mouth of Liaoning's Yalu River and run south as far as the mouth of Guangxi's Beicang River under continuous jurisdiction (including in it the sea area under the jurisdiction of Taiwan Province)--by preliminary statistics--there is a requirement for the laying out of 450 geodetic control points. Only then is it possible to create land-sea geodetic datums on the entirety of China's national oceans and territory. There is no way that this can be completed with regard to conventional geodetic surveys. It is only with the use of GPS satellite positioning technology that it is then possible to rapidly and economically complete this important task associated with the 450 oceanic geodesy point positions. The economic benefits are difficult to represent using numbers.

In order to satisfy requirements associated with maritime target ranges, the general staff map making research institute has set up a GTH warship real time dynamic position survey system. It is primarily based on GPS difference dynamic measurement technologies, carrying out multiple target, surface warship real time dynamic measurements. The development costs associated with GTH systems are only 1/25 those associated with traditional optical systems. Equipment expenses alone then save 14 million 420 thousand Renminbi. Due to the fact that GTH system cost benefits are comparatively high, each year, 6.06 million Renminbi are also saved in operating expenditures. If option is made for the use of 10 sets of GTH systems, GPS economic benefits are capable of reaching 200 million yuan (Renminbi).

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Statistics for the year 1980 clearly show that Chinese railroad turnover amount is 57.07 billion ton-kilometers. If people follow on to the year 2000 in accordance with a quadruple calculation, China's railroad turnover amount will reach 2.2828 trillion ton-kilometers. This will then require the setting up of a good number of new railroads. If each train has installed on it a GPS receiver unit as well as other data transceiver equipment, it is possible to make the travel interval time periods shrink from the current 9 minutes to 3 minutes. This is at least capable of making the transport capabilities which railroads currently have increase one fold. This is the equivalent of constructing 100% of new railroad. Even if each ton-kilometer is figured as 0.1 yuan, it is still possible to make a profit of 171.2 billion yuan (Renminbi). In this one example alone, it is possible to know that GPS satellites are capable of creating for us such enormous economic benefits.

III. GPS REVELATIONS

Following along with the flourishing development of GPS technology and applications in all fields, the high cost benefits associated with GPS satellites will also be shown even more fully. From the few points discussed above alone, it is sufficient to make us grasp the revelations described below.

1. Strengthening Satellite Applications, Slacking Off on Material Security, and Encouraging Scientific and Technical Personnel from Many Disciplines to Participate in the Development of Astronavigational Applied Technologies.

As far as GPS global positioning satellite systems are concerned, they are second generation military use satellite navigation systems controlled by the U.S. Department of Defense. However, they incite broad research by scientific and technical personnel domestically and abroad into GPS satellite applications, providing for them a good number of precious materials associated with GPS satellite applications. When the first GPS test satellite entered into orbital operations on 22 February 1978, with very long baseline radio interference (VLBI) technology rapidly developing, geodesy experts were acutely aware that the altitudes of GPS satellites off the ground must be much nearer than the type of quasi stellar body (Quasar) used by VLBI. The signal strength of the former is $1.7E-21/m^2 \cdot Hz-2.8E-21/m^2$.

This is around one hundred thousand times greater than the radio signal strength of this type of quasi stellar body. Using GPS satellite radio signals to survey the globe is necessarily much simpler than VLBI. In the fall of 1978, Dr. P.F. MacDoran of the California Science and Engineering Institute Jet Propulsion Laboratory (JPL) put forward the concept of a satellite radio interference survey system (SERIES). In conjunction with this, in 1980, successful development was done of SERIES-X model GPS signal receivers. At the same time as this, scholars such as Professor C.C. Counselman of the U.S. Mashao (phonetic) Science and Engineering Academy--on the foundation of MITES small model radio interference geodetic systems--successfully developed in April 1981 Macrometer interference measurement devices. Experiments on a 1km baseline clearly showed that, opting for the use of 2 hour GPS positioning data, it is possible to reach three

dimensional position precisions of $\pm 5\text{mm}$. This gave great encouragement to developers and users. In December of 1982, they then put out onto the market the first batch of Macrometer V-1000 interference measurement instruments. From the above, it is possible to see that:

(1) As far as the development of astronavigational applied technologies is concerned, it is certainly not only capable of relying on astronavigational technology experts. Science and technology personnel outside the realm of astronavigational technology often are very sharp in astronavigational technologies within their own explorations. The applied researchs of the several geodetic experts discussed above are then one example. With regard to codeless GPS receivers developed by them, they laid a theoretical and technical foundation for today's high precision measurements and made important contributions to opening up fields of GPS satellite applications.

(2) The primary objective associated with the launching of GPS test satellites was to check out the basic functions of GPS systems in order to make technical preparations for the launch of GPS operating satellites in the formal operational phase. However, not long after GPS test satellites entered into operations, applications research associated with GPS satellites developed vigorously. By the time that the first GPS operating satellite entered into orbital flight on 12 February 1989, GPS satellite applications had already achieved abundant results. Several tens of types of GPS signal receivers with various different uses had already appeared in large numbers on international markets. For this reason, it is possible to see that, only so long as satellite applications are strengthening is it then possible to break into markets and produce economic benefits which exceed investments.

2. Seizing Opportunities, Opening Up Markets, and Constantly Creating New Scientific and Technical Results

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As far as the enormous role which GPS played during the Gulf War is concerned, it inspired the developers of GPS systems and infused great new energy into GPS satellite applications. Taking uses of GPS by foreign militaries alone as an example, since 1992, the three land, sea, and air services of such nations as the U.S., the U.K, France, Holland, New Zealand, Australia, and so on, have already signed contracts to purchase over 200 thousand GPS signal receiver units in order to equip their various types of missiles, aircraft, warships, tanks, and small infantry detachments. Various firms have seized the opportunity, following the Gulf War, to rapidly expand GPS applications in order to open up broad new domestic and foreign markets for the sale of GPS signal receivers. As far as the spacecraft which China has already launched aloft or are just about to enter orbital operation are concerned, is it not difficult to believe that it will not be possible to achieve some revelations from GPS satellite applications?

Before the year 1989, Chinese users had difficulty purchasing GPS dual frequency receivers. In the spring of 1989, when the author ordered GPS dual frequency receivers for the Wuhan Map Making Science and Technology College--in order to obtain as rapidly as possible import permits--he also wrote a letter of request to the U.S. government in the name of a professor, at the suggested direction of the national education committee's World Bank loan office. However, after a year, the U.S. government then canceled restrictions on the export of GPS dual frequency receivers. The reason was that GPS dynamic carrier wave phase measurement technology had already become nearly familiar. In order to expand GPS markets--adapting to the requirement for great international cooperation--it was possible to use fruits of new science and technology to replace the security associated with dual frequency technologies. Any security was of a time limited nature in all cases. In particular, security associated with the products of science and technology possessed an even more strongly time limited nature. Only when new achievements of science and technology are ceaselessly created is it then possible to maintain a position of leadership. With regard to navigation messages which Russian GLONASS satellites send, initially, they were strictly secret. However, such people as Dr. G.R. Lennen of the U.K.'s Leeds College ended up breaking the C/A code and P code associated with GLONASS signals. In conjunction with this, they were made public to the world, thereby forcing Russia to declassify GLONASS.

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